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Discovering the true wind resource: Including hi-res terrain effects for a new and global wind atlas

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Discovering the true wind resource: including hi-res terrain effects for a new and global wind atlas.

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Summary of Global Wind Atlas project

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The global wind atlas objectives are:

- provide wind resource data accounting for high resolution effects
- use microscale modelling to capture small scale wind speed variability
- use a unified methodology
- verify the results in representative selected areas
- give comprehensive uncertainty estimates
- publish the methodology to ensure transparency

- be applied for aggregation and upscaling analysis and energy integration analysis for energy planners and policy makers

SRREN report: range tech. pot. 19 – 125 PWh / year (onshore and nearshore)

Current situation

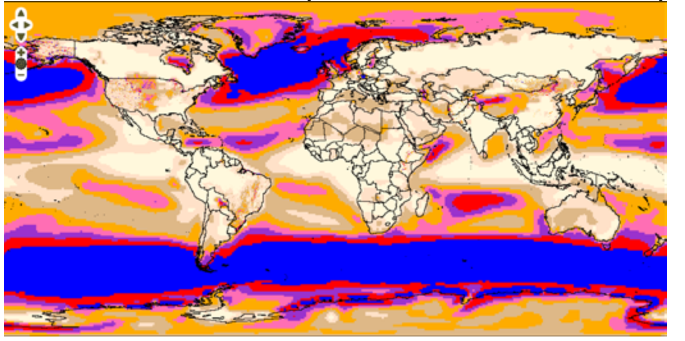
Public datasets

- Global coverage at coarse resolution
- Ad hoc coverage at high resolution
  - Disparate methodologies
    (model types, sources of input data)
  - Different reference periods
    (pertinent time period)
  - Different resource products
    (how the wind data is expressed)

Private datasets

- Impressive scope of products
- Available on commercial terms
- Coupling with assessment tools
- Some verification included
- Methodologies - part of company's commercial interests

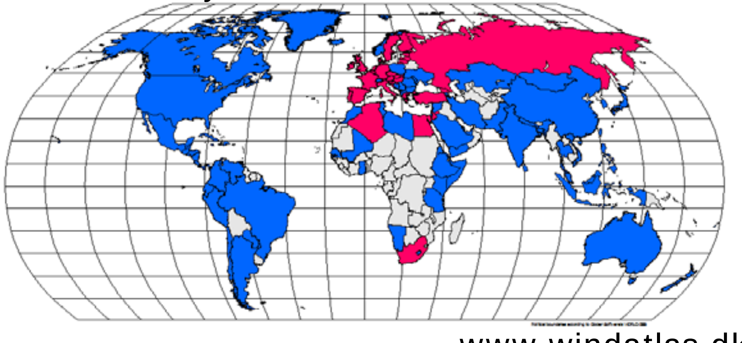
Coarse resolution (~100 km NASA data)



SWERA medium resolution (1 – 5 km)

RREX via swera.unep.net

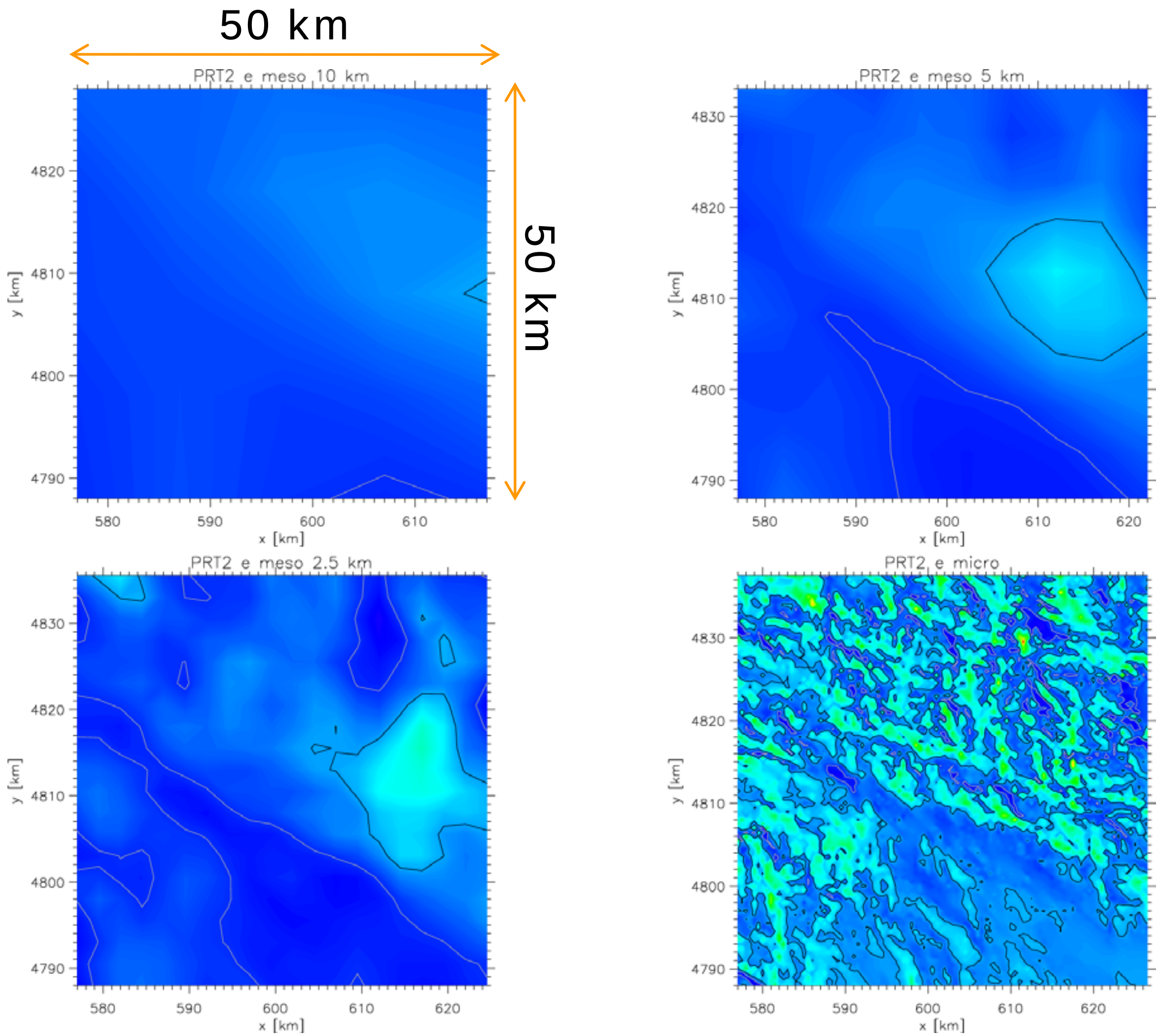
WAsP analysis and atlas data available



www.windatlas.dk

Importance of resolution

Wind resource (power density) calculated at different resolutions



10 km

324 W/m²

378 W/m²

5 km

328 W/m²

398 W/m²

2.5 km

323 W/m²

410 W/m²

0.1 km

505 W/m²

641 W/m²

mean power density of total area

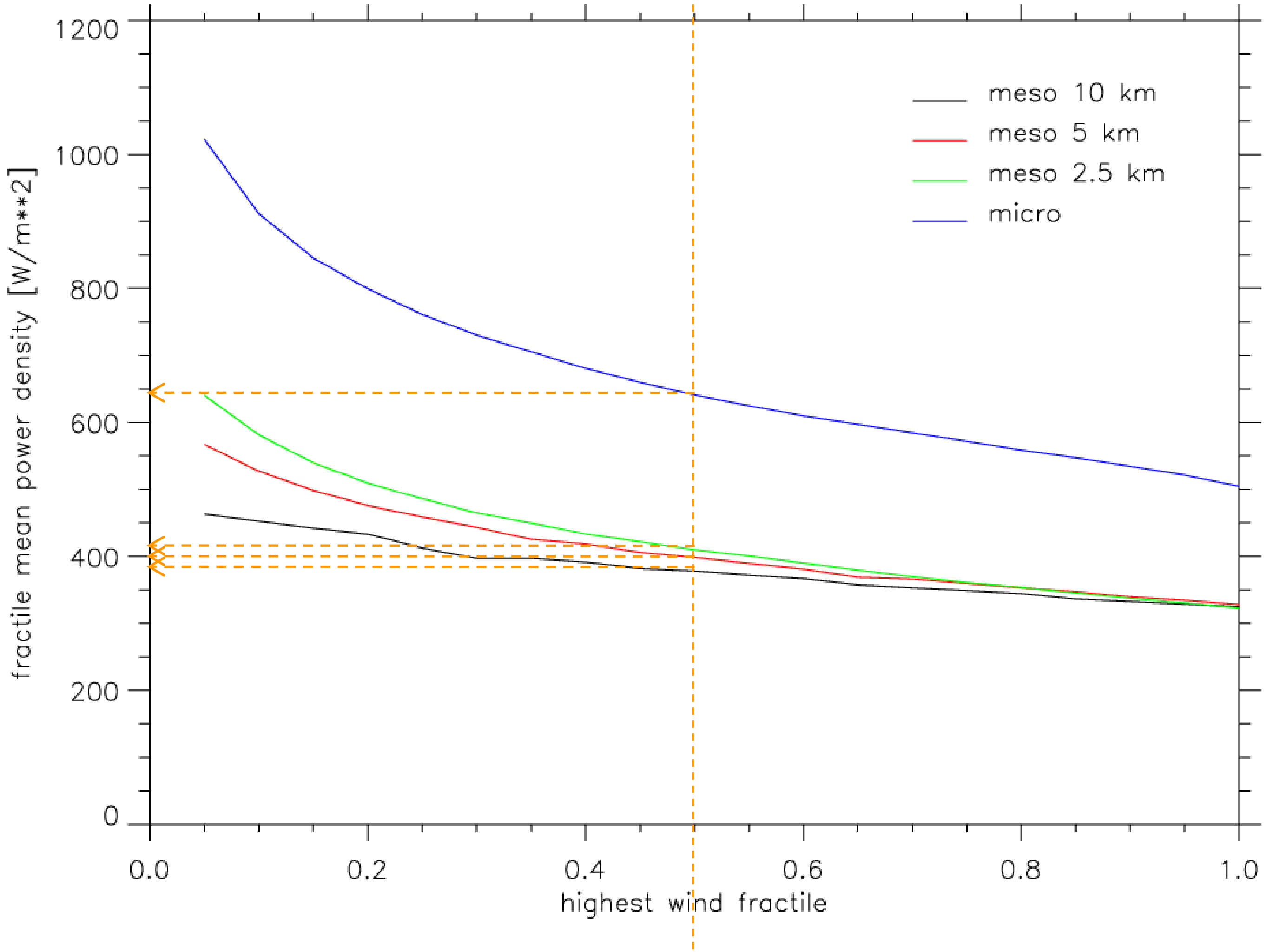
mean power density for windiest 50% of area

Importance of resolution

Note:

This area exhibits large topography effects.

Even for Danish landscape effect can give 25 % boast in wind resource at the windiest 5 percentile.



Mean wind power density for windiest half of area

Input: newly available global dataset

Reanalysis: atmospheric data

Product	Model system	Horizontal resolution	Period covered	Temporal resolution
ERA Interim reanalysis	T255, 60 vertical levels, 4DVar	~0.7° × 0.7°	1989-present	3-hourly
NASA – GAO/MERRA	GEOS5 data assimilation system (Incremental Analysis Updates), 72 levels	0.5° × 0.67°	1979-present	3-hourly
NCAR CFDDA	MM5 (regional model)+ FDDA	~40 km	1985-2005	hourly
CFSR	NCEP GFS (global forecast system)	~38 km	1979-2009 (& updating)	hourly

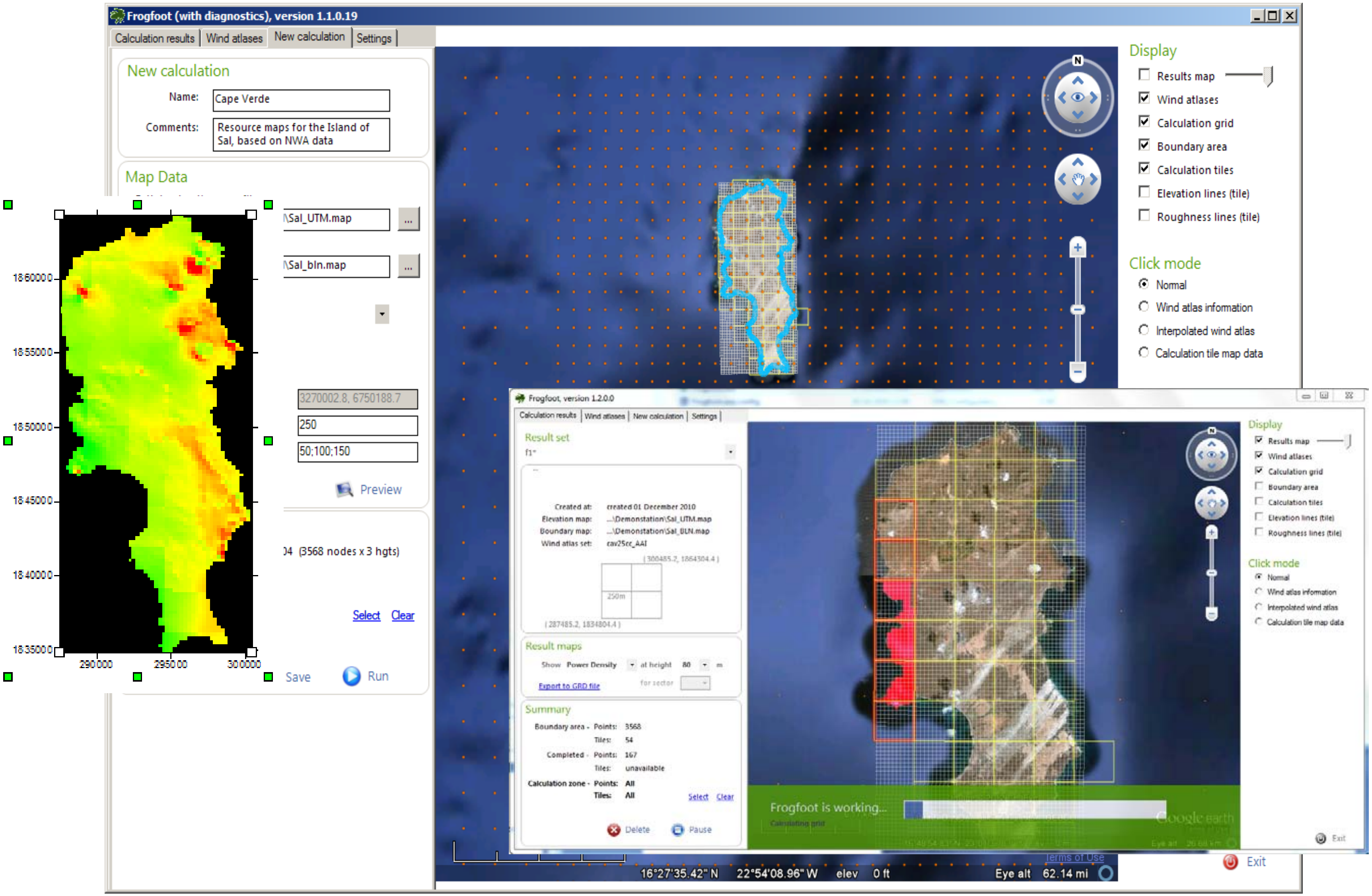
Topography: surface description

<u>Elevation</u>
Shuttle Radar Topography Mission (SRTM), version 2.1, released 2009 — resolution 90 m
ASTER Global Digital Elevation Model (ASTER GDEM), version 1, released 2009 — resolution 30 m

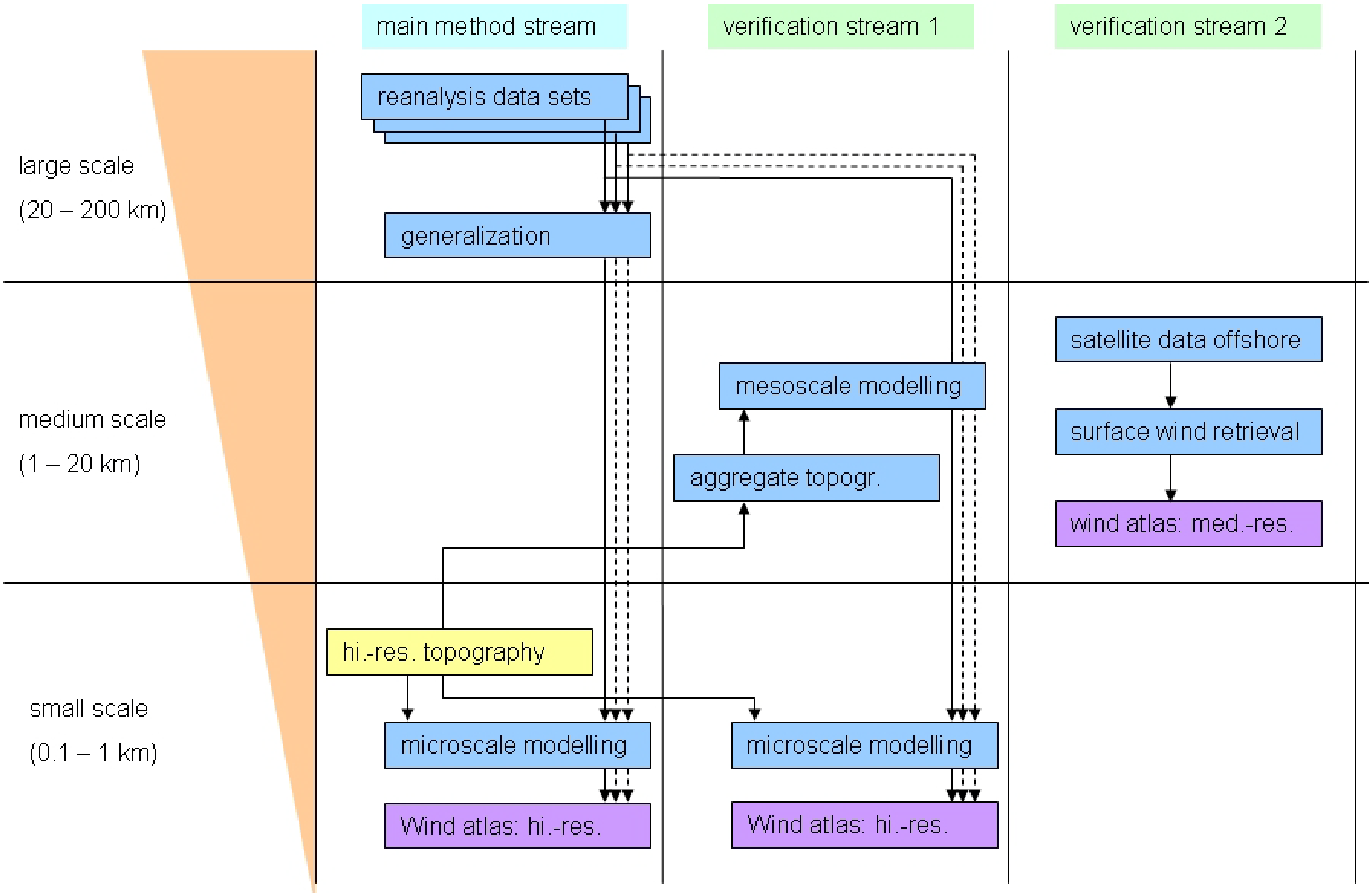
<u>Land cover</u>
ESA GlobCover, version 2.1, released 2008, — resolution 300 m

By using a range of input sources an ensemble of wind resource data can be calculated and help assess uncertainty, quality of data and proper treatment of various input datasets.

Application of microscale model

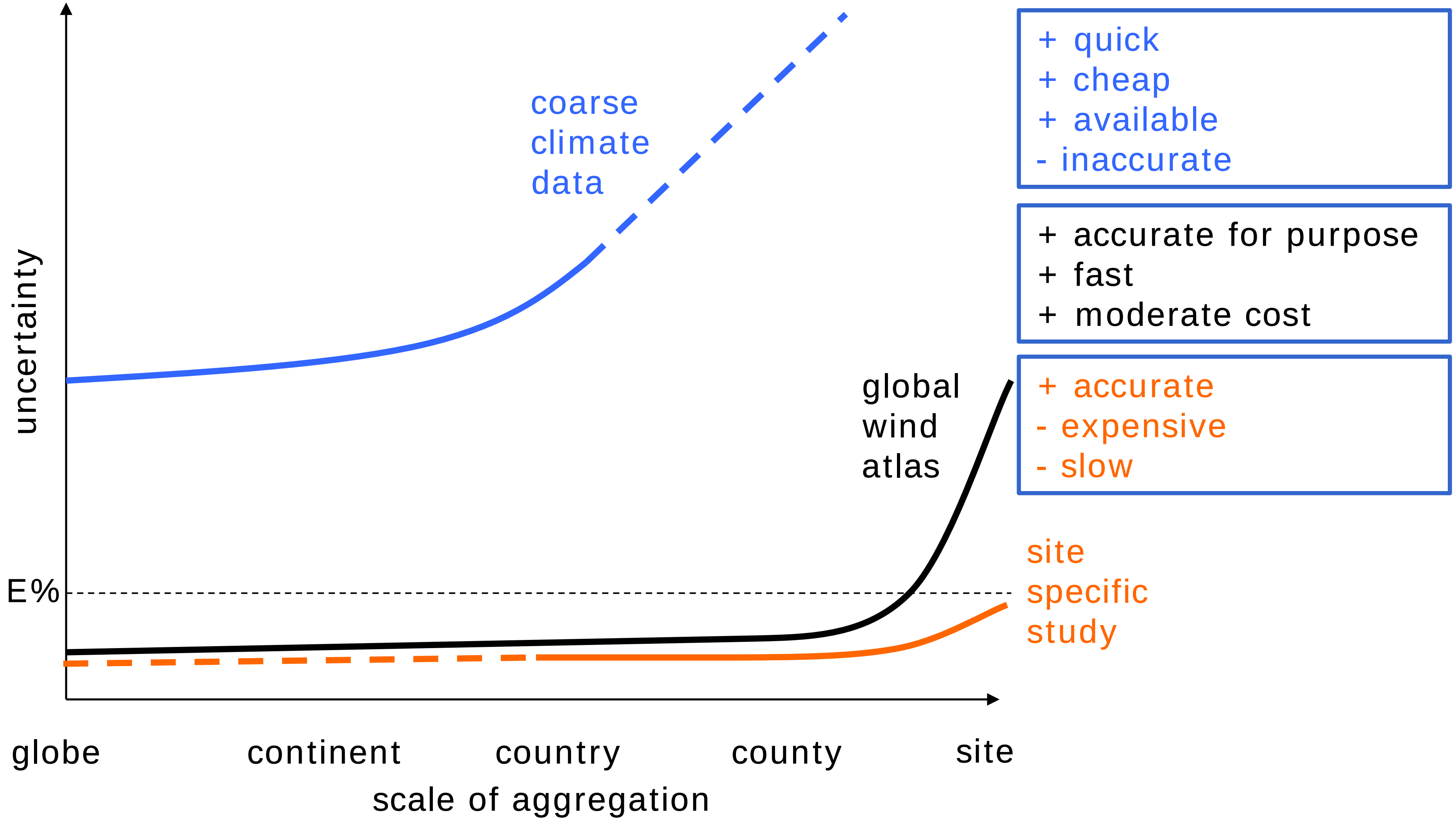


Project overview



Aggregation

Schematic graph showing uncertainty as function of scale of aggregation for various wind resource mapping methodologies



Why is resolution so important?

$$e = \frac{1}{2}\rho u^3$$

wind power density, W/m^2

$$u = \bar{u} + u'$$

time mean and perturbation

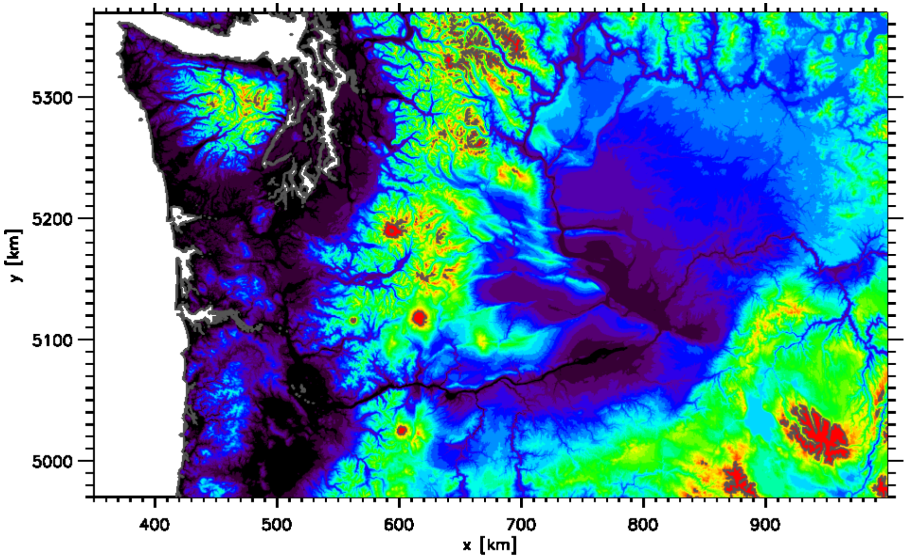
$$\bar{u} = [\bar{u}] + \bar{u}^*$$

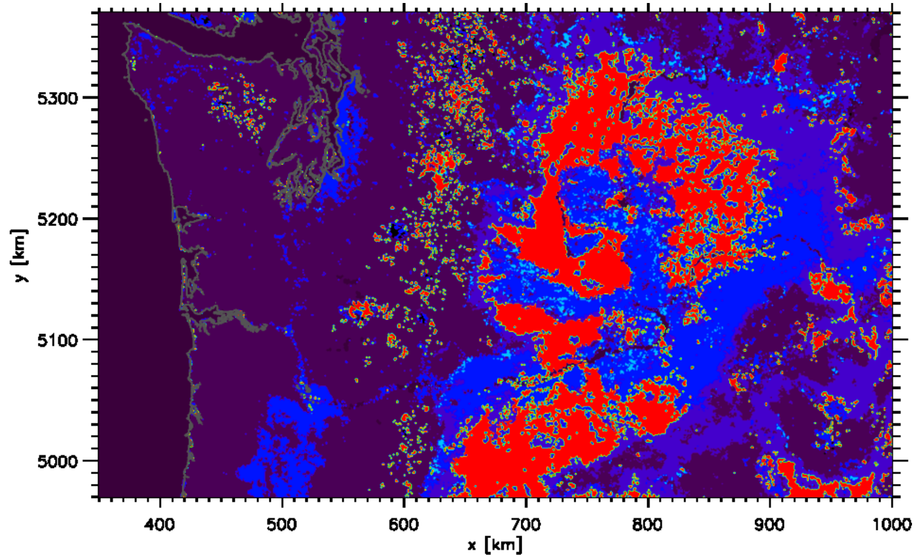
spatial mean and perturbation

$$[\bar{e}] \neq \frac{1}{2}\rho([\bar{u}]^3)$$

$$[\bar{e}] = \frac{1}{2}\rho([\bar{u}]^3 + \underbrace{3(\sigma_A^2[\bar{u}] + [\sigma_T^2][\bar{u}] + [\sigma_T^{2\,*}\bar{u}^*]))}_{\text{need to account for temporal and spatial variance}}$$

Example: Columbia Gorge area, USA





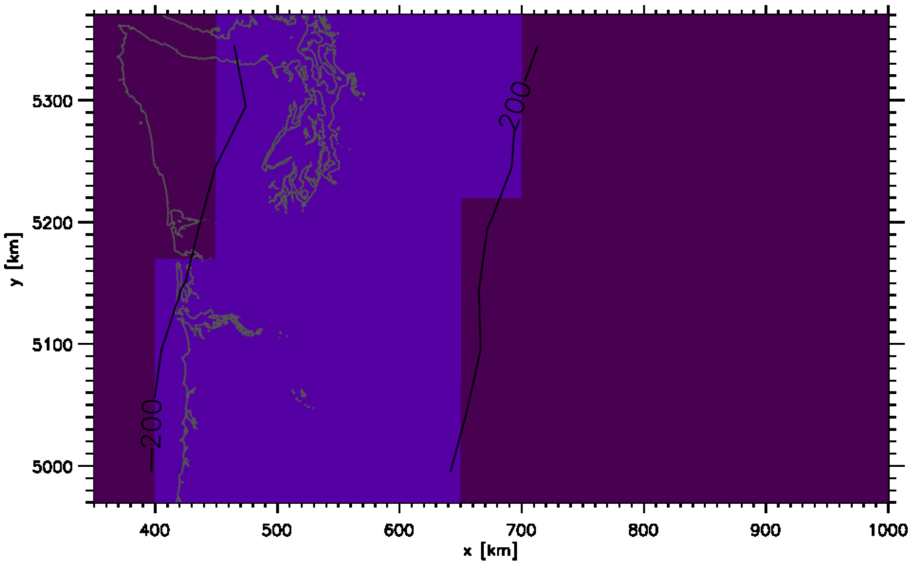
Orography (elevation) of the 650 x 400 km Columbia Gorge test region located in north-western USA.

The elevation ranges from 0 m as the sea to over 2000 m in the mountains.

Variations in the surface roughness length for the 650 x 400 km Columbia Gorge test region.

Example: Columbia Gorge area, USA

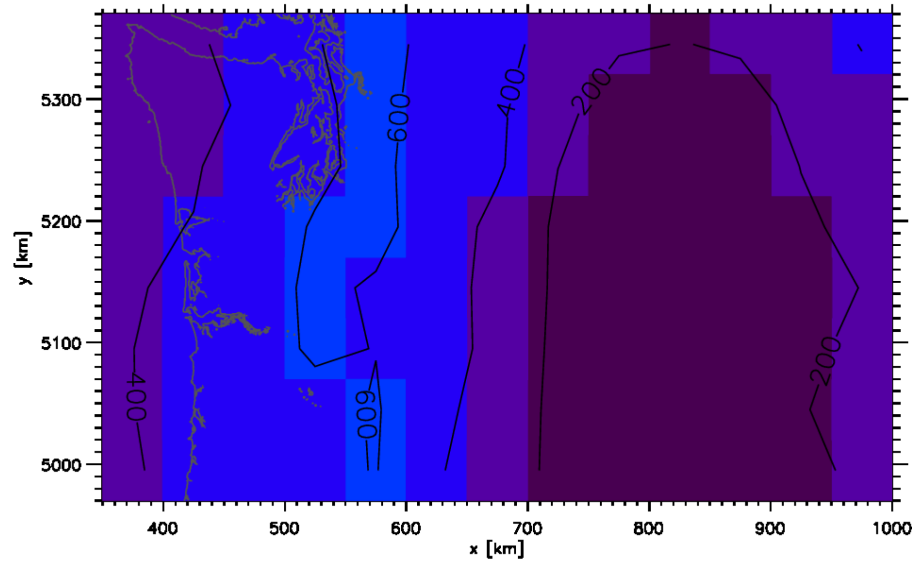
Wind power density at 50 m



$$\frac{1}{2}\rho([\bar{u}]^3)$$

Based on spatial and time mean wind speed at 50 km resolution.

Temporal and spatial variance not accounted for.



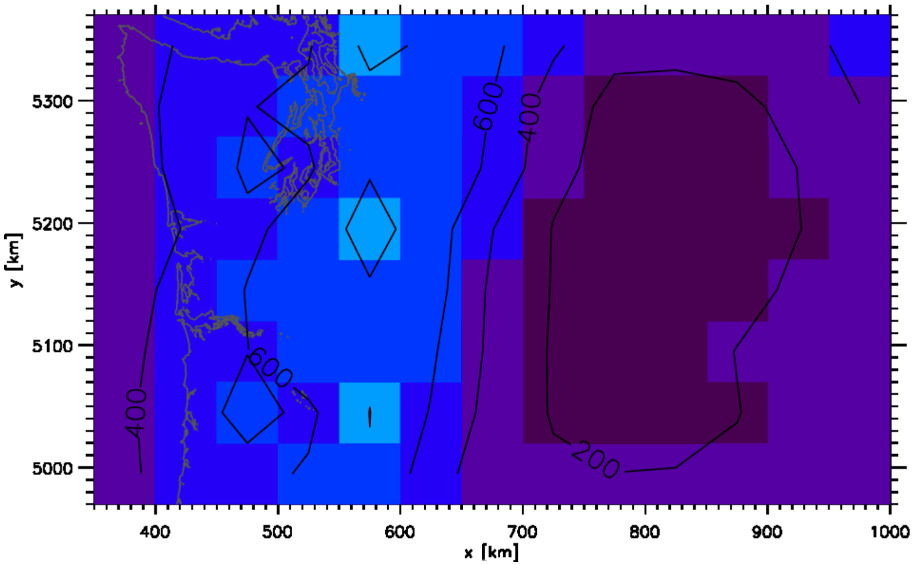
$$\frac{1}{2}\rho(\overline{[u]^3})$$

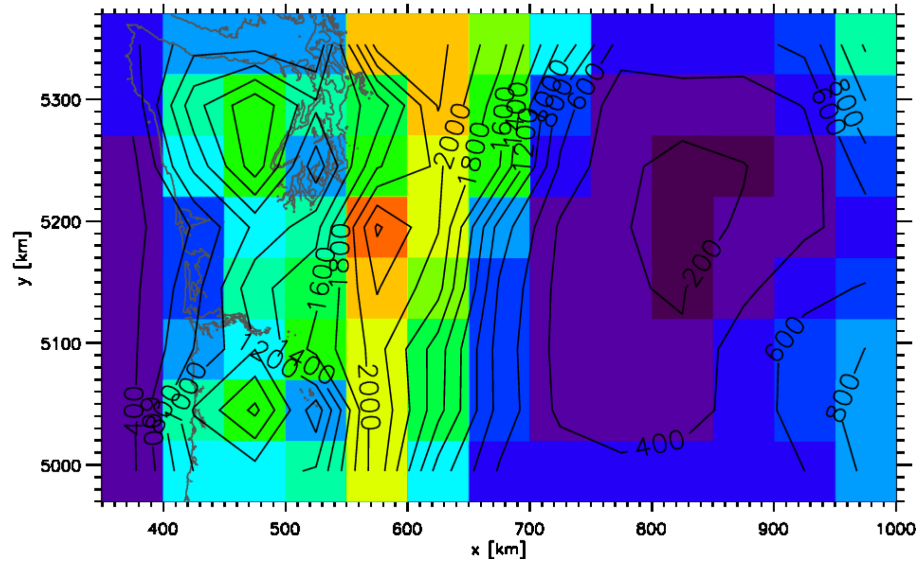
Based on spatial mean wind speed at 50 km resolution.

Spatial variance not accounted for.

Example: Columbia Gorge area, USA

Wind power density at 50 m





$$[\bar{e}] = \frac{1}{2}\rho([\bar{u}]^3 + 3(\sigma_A^2[\bar{u}] + [\sigma_T^2][\bar{u}] + [\sigma_T^{2\,*}\bar{u}^*]))$$

Based on spatial and temporal mean wind speed at 50 km resolution

Spatial and temporal variance accounted for

Wind power density at 50m for the top 10-percentile (windiest 1/10th of the area)

Based on spatial and temporal variance and an assumed wind speed distribution, it is possible to determine a distribution of wind power density.

Summary

Discover the true global wind resource and make it available for all

- provide wind resource data accounting for high resolution effects
- use microscale modelling to capture small scale wind speed variability
- use a unified methodology
- verify the results in representative selected areas
- give comprehensive uncertainty estimates
- publish the methodology to ensure transparency
- **be applied for aggregation and upscaling analysis and energy integration analysis for energy planners and policy makers**

Thank you for listening

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